Interim Report on Geochemical Results of Production Test of HGP-A

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The primary objectives of the chemistry group efforts during the two-week test of the HGP-A well were as follows:

1) determine the quantities and concentrations of the major chemical constituents in the geothermal fluids produced;
2) test out and refine sampling and analytical procedures for the well fluids as these procedures have been modified for HGP-A;
3) identify and quantify potential environmental pollutants produced by HGP-A;
4) attempt, on the basis of the gas and water chemistry data obtained, to identify potential reservoir or plant engineering problems which might arise in the future due to present or anticipated production characteristics of HGP-A.

Sampling and Analysis Procedure

The sampling and analytical procedures applied during the two-week test of HGP-A were generally similar to those outlined in the publication "Sampling and Analysis Methods for Geothermal Fluids and Gases" (J.C. Watson, ed., Batelle Northwest Laboratory) although some techniques were slightly modified to suit the conditions in the field.

Fluid samples were obtained as follows:

ANX-1 Steam line immediately downstream of separator. Samples of steam condensate and non-condensable gas were obtained for on site and later laboratory analysis of concentrations of H_2S, CO_2, H_2, N_2, and Cl^- in the steam phase; the latter for a determination of the steam quality (blow over) coming from the well-head separator. Several sampling procedures were applied at this sampling point: steam condensate and gas

was condensed directly into evacuated flasks (some containing NaOH solution and some entirely empty) steam and noncondensable gases were passed through a condenser coil and then into evacuated flasks containing NaOH; steam and noncondensable gas were passed through a condenser coil and into a cascade type equilibration chamber where the liquid condensate and dissolved gas were allowed to equilibrate at atmospheric pressure, the gases then being sampled at the gas outlet of the equilibrator. The analytical procedures applied include both wet chemical analysis of the sulfide carbonate, and chloride as well as gas analysis by gas chromatography and using draeger tubes.

The most successful procedure applied was found to be direct condensation of the steam phase into a sodium hydroxide solution; gas analysis of H_2 and N_2 by chromatography and titrametric analysis of H_2S and CO_2 using a specific ion electrode for the former and a standard pH alkalinity titration for the latter. Although gas analysis using the draeger tubes was very fast and extremely simple, quantitative analysis of the gas chemistry is severely hampered by the solubility of CO_2 and H_2S in the condensate and the slow rate of equilibration between the gas and liquid phases.

ANX-1-A Well discharge line immediately downstream of well head wing valve and upstream of well head separator. Samples of total fluid flow were obtained for chloride, silica, and gas analysis. Initial sampling indicated that representative and reproducable

samples of liquid and steam phases were not obtainable at this point and for this reason no further sampling was pursued here.

ANX-2 Brine discharge line immediately downstream of well head separator. Samples of water were obtained at this point for wet chemical analysis of chloride, fluoride, carbonate, sulfate sulfide, sodium, potassium, calcium, magnesium, ammonia, arsenic, bonon, iron, lead, and thallium. On site analyses were done only for chloride, carbonate, sulfide and silica. The former three constitutents were analyzed by titrametric techniques and the last by spectrophotometry. Samples were obtained and preserved, following the procedures outlined by Watson ("Sampling and Analysis Methods for Geothermal Fluids and Gases") for later laboratory analysis of the remainder of the dissolved constituents.

ANX-3 Steam discharge line immediately downstream of the caustic mixing chamber. Samples from this port were obtained for analysis of sulfide and carbonate in the steam and liquid phases. Samples of the liquid phase were collected directly whereas the steam phase was condensed in a condenser coil and collected in a sodium hydroxide solution. All samples were analyzed by wet chemical techniques. In that the steam pressure at this point was very low, it was extremely difficult to efficiently separate the liquid and gaseous fractions at this port. Available

separators were designed for high pressure separation and therefore it was necessary to design a very crude arrangement to obtain even marginally reliable samples. Any further detailed studies of the mixing and kinetics of the caustic injection system require substantially more sophisticated sampling ports than were available.

ANX-4 Steam discharge line immediately downstream of peroxide mixing chamber. Samples were obtained for analysis of sulfide and carbonate in the liquid and gas phases at this point. Sampling and analysis procedures were identical to those for ANX-3. The problems associated with sampling at this point were identical to those at ANX-3.

ANX-5 Steam discharge at the sparger pit. This sampling point consisted of a stainless steel pipe which entered the sparger pit below the rock muffler. Samples of steam were obtained at this point for analysis of hydrogen sulfide and sulfur dioxide. The very low pressures at this port also produced several sampling difficulties; the net result being that samples were obtained by pumping the steam discharge through a condenser coil and bubble train to remove the acid gases. The primary difficulties encountered when applying other techniques ranged from inadequate separation of liquid and steam phases to unrepresentative fractions of non-condensable gases being collected with the steam fraction.

Sparger pit discharge line: discharge line located at bottom of sparger pit to drain the NaOH - Na_2S - Na_2SO_4 liquor to waste. Samples at this location were obtained for the analysis of pH, total sulfide and total sulfate removed from the steam discharge. Analysis of sulfide and sulfate were by standard wet chemical methods. No difficulties were encountered in the sampling and analysis at this port.

Sparger Pit Plume

Samples of steam discharge from the top of the sparger box for determination of pH and H_2S concentrations. Sampling techniques utilized a pump-condenser coil-bubble trap train. Analysis of the condensate for pH and sulfide were by standard techniques. Direct sampling and analysis of the steam plume was also done using draeger H_2S and SO_2 analysis tubes. The former sampling technique encountered difficulties arising from unrepresentative sampling of the steam and condensate phase. Results of the draeger tubes H_2S analyses were somewhat more reproducable although the reliability of the analyses are somewhat questionable as a result of variable amounts of air mixing in the steam plume. Analysis of sulfur dioxide using the draeger tubes was found to be generally unreliable due to "wash-out" of the tube reagent by the steam condensate. This problem was most acute with tubes designed for high concentrations of SO_2 whereas those designed for low level analysis did not exhibit this characteristic.

Weirbox

Brine discharge: line immediately downstream of the twin stack separators. Samples were obtained for chloride analysis only.

Samples were dipped directly out of the Weirbox discharge notch. Chloride analyses were done by standard titrometric methods. No significant problems were encounterd with the samples obtained at this point.

The results of water and gas analyses done in the field during the test period are presented below. Although a large number of samples were obtained during the test for later laboratory analysis, only a limited number of these data are presently available. Analysis of the remaining samples is continuing. In addition to those samples acquired specifically for later analysis duplicates of many of the samples obtained for field analysis have been preserved for later laboratory confirmation of the field results.

In general terms the field sampling and analytical program throughout the two-week flow test could be considered a moderate success; those data most important for the successful completion of the test and for the final plant design were acquired. However, some of the subsidiary data which were considered useful for the study of the kinetics of the caustic-peroxide injection system were not acquired in the detail or to the accuracy desired by the chemistry supervisors. Future efforts on these latter studies will require a somewhat different design for sample removal and separation.

Water Chemistry

Chloride

Figure 1 presents a plot of chloride concentration in the weirbox water versus log of time through the duration of the well test. The trend of increasing chloride with time is apparent and shows no significant break point at which the chloride concentrations begin to level off. There are short term variations superimposed over the generally increasing trend which are undoubtedly the result of changes in flow rate and well head pressure (see below). Previous flow tests of HGP-A have also produced similarly increasing chloride concentrations with time, although the most recent results indicate a somewhat more rapid rise to slightly higher chloride values than were previously observed.

The data presently available strongly suggest that the source of the chloride ion, as well as most of the other major ions, is derived from seawater intrusion into the geothermal reservoir. If the trend of increasing chloride continues, it is conceivable that the chloride concentration could ultimately reach 48,750 ppm. This value corresponds to pure seawater from which 60% of the water has been removed as steam. Although the rate of chloride increase during the test was quite high, tritium data (see below) on the discharge water suggests that the natural rate of increase will be substantially less rapid.

The short term variations in the chloride chemistry can be correlated with changes in well head pressure as plotted in Figure 2. Although both the chloride and pressure curves have been considerably smoothed it is apparent that a decrease in flow rate, and consequent increase in well head pressure, results in a decrease in the chloride concentrations observed. All the chloride values plotted are from the weirbox samples, and thus were obtained at the same temperature and pressure.

Figure 1

Weirbox Chloride Concentration Versus Log Time

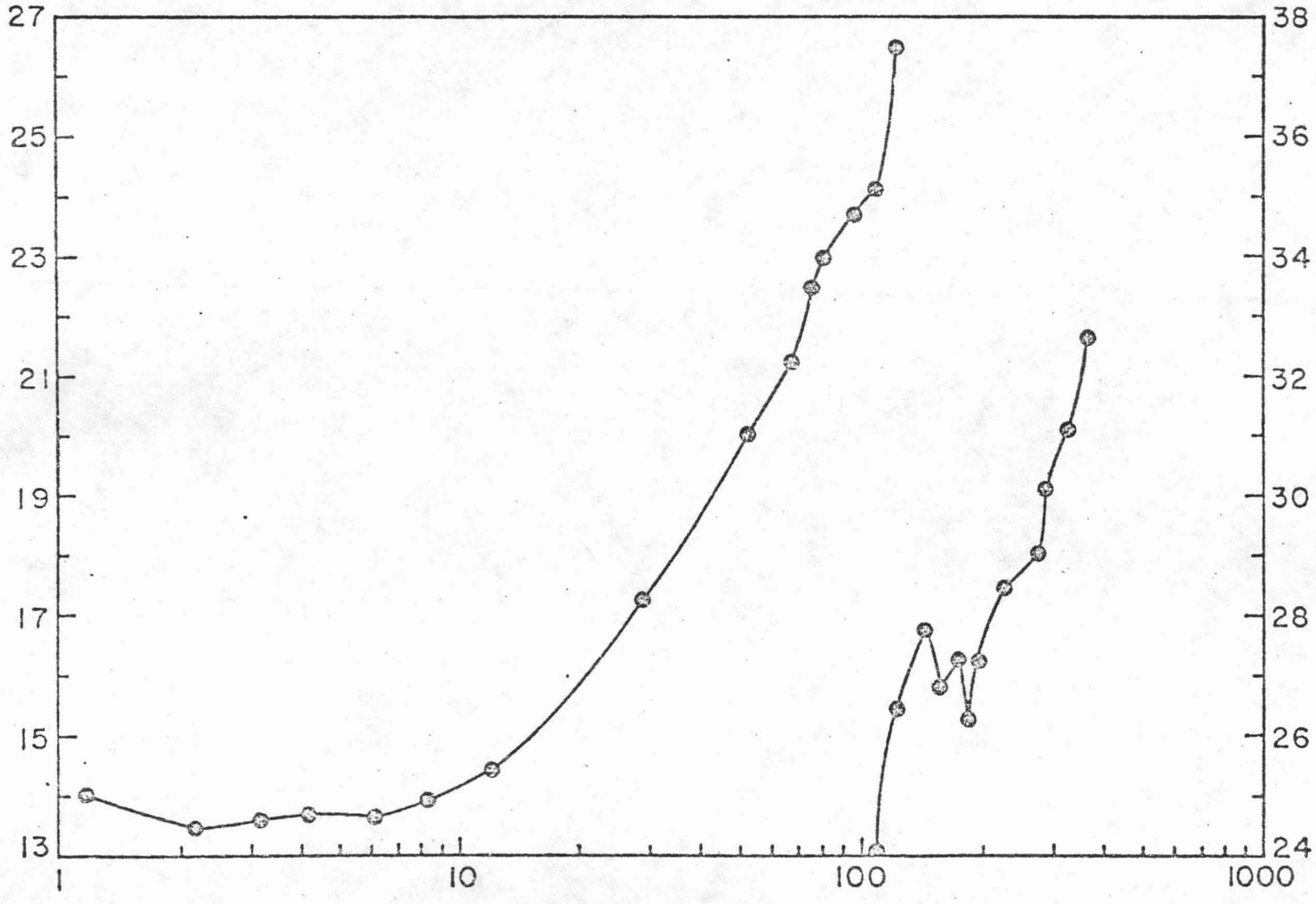
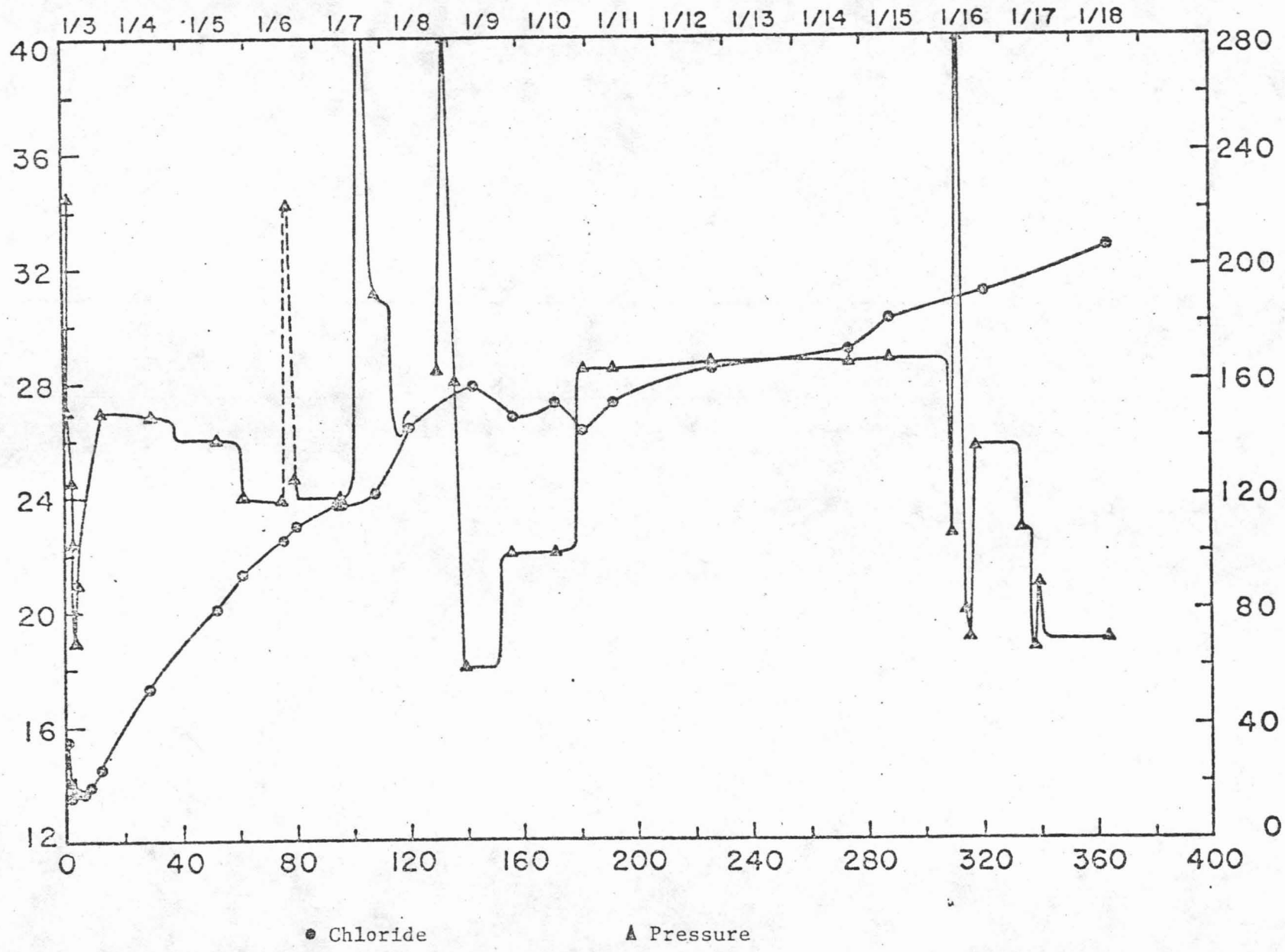


Figure 2

Weirbox Chloride Versus Time and Pressure Versus Time



When these chloride data are calculated back to constant temperature and pressure flash the chloride concentrations in the effluent water are somewhat lower at the high discharge pressure than can be accounted for simply by changes in the percentage of flash from a constant chloride reservoir fluid. It is possible that the small differences observed are the result of changing production rates from different aquifers at the higher and lower pressures. However, at present, more precise pressure-temperature and chloride concentration data are necessary before any definite conclusions can be drawn.

The chloride concentrations determined for brine samples obtained at the separator outlet follow a trend similar to that for the weirbox samples. The slightly lower chloride concentrations observed in the separator brine correspond to the lower fraction of steam formation for the high temperature brine samples.

Cation Chemistry

The remainder of the brine chemistry is summarized in Table 1 and Figures 3 and 4. Figure 3 presents a bar graph of the major chemistry expressed as percentages of seawater ion concentrations. The highest and lowest ion concentrations observed in the sample set are as indicated on the bar graph for each ion. If one assumes that the chloride ion concentration is representative of the seawater mixing it is apparent that there has been a slight enrichment in the sodium ion concentrations and a much greater enrichment in potassium whereas calcium and sulfate have been heavily depleted and magnesium removed almost completely. These trends are virtually identical to those observed in earlier production tests of HGP-A and present no significant deviations from its earlier behavior.

One question of importance to the future productivity of the well is the mechanism for the depletion of some of the seawater ions. It is generally understood that magnesium is removed through the formation of the hydrothermal

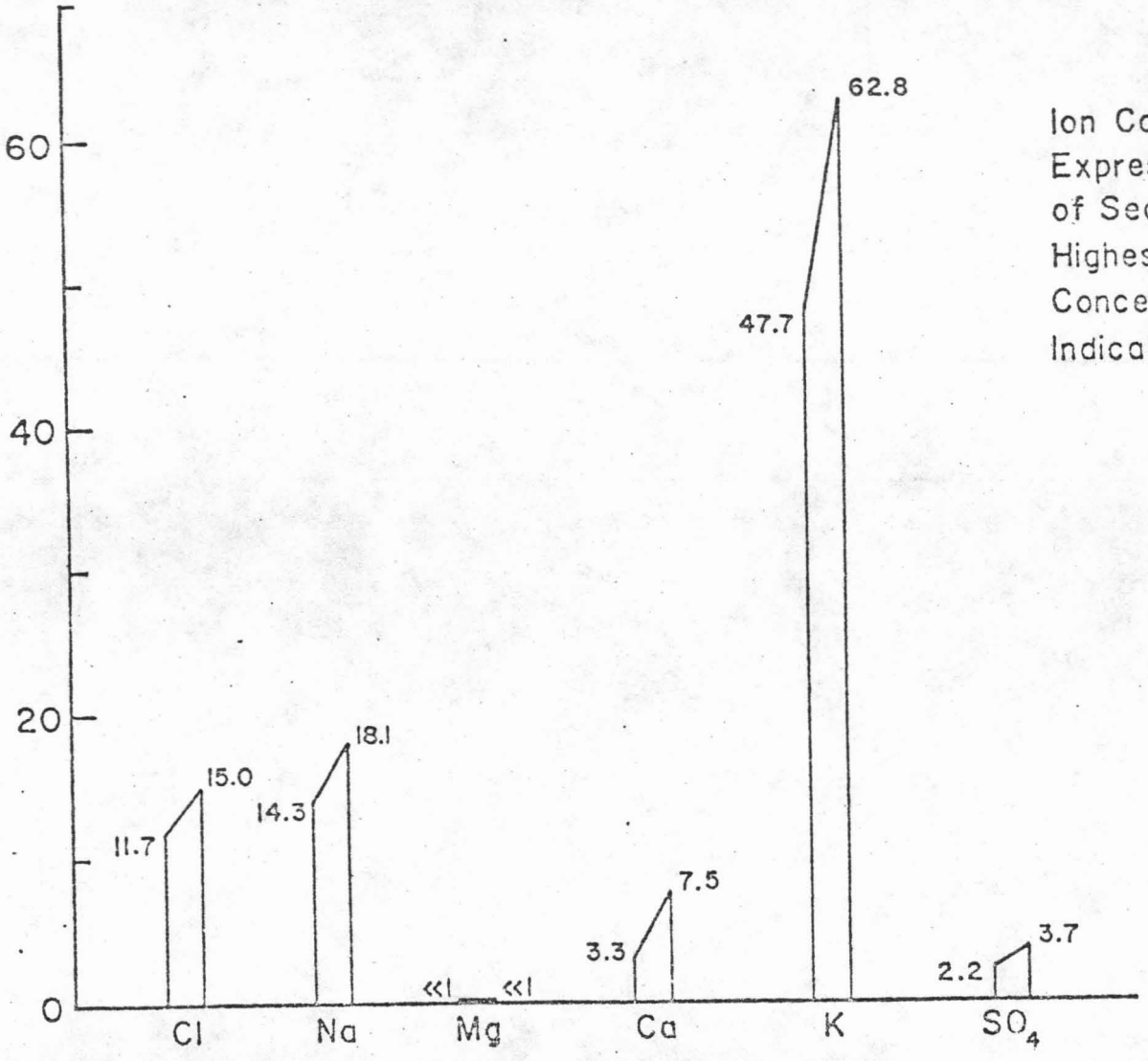
Table 1

Brine Chemistry

Date	Location	Time	"Pre-treatment"	Sep Press Psig	mg/Lit. Cl	mg/Lit. Na	µg/Lit. Mg	mg/Lit. Ca	mg/Lit. K	SO_4	SiO_2	
1/10/80 St. Pt. 1	ANX-2	1000	Raw Untreated	88	2390	1430	≤10	16.3	200	50	865	4951
1/10/80 St. Pt. 1	ANX-2	1000	Filtered Untreated	88	2390	1432	≤10	14.9	195	64		
1/10/80 St. Pt. 1	ANX-2	2036	Raw Untreated	88	2410	1445	≤10	15.7	198	48		
1/11/80 St. Pt. 2	ANX-2	1300	Raw Untreated	154	2450	1463	≤10	33.2	211	60	792	5009
1/11/80 St. Pt. 2	ANX-2	1300	Filtered Untreated	154	2290	1380	≤10	29.8	208	59		
1/11/80 St. Pt. 2	ANX-2	1300	Raw Untreated	154	2300	1357	≤10	26.6	205	55		
1/12/80 St. Pt. 2	ANX-2	1615	Raw Untreated	155	2350	1405	≤10	25.9	204	62		
1/12/80 St. Pt. 2	ANX-2	1615	Filtered Untreated	155	2356	1423	≤10	27.2	190	67 74		
1/14/80 St. Pt. 2	ANX-2	1215	Raw Untreated	156	2450	1440	≤10	30.5	205	60	796	4982
1/14/80 St. Pt. 2	ANX-2	1215	Filtered Untreated	156	2450	1434	≤10	31.1	212	65 69		
1/16/80 132 psi	ANX-2	2020	Raw Untreated	130	2600	1530	≤10	33.2	216	67	832	5278
1/16/80 132 psi	ANX-2	2020	Filtered Untreated	130	2593	1520	≤10	33.9	224	69.3		
1/17/80 56 psi	ANX-2	1630	Raw Untreated	52	2920	1713	≤10	17.9	247	59 73	875	5846 5551
1/17/80 56 psi	ANX-2	1630	Filtered Untreated	52	2930	1723	≤10	17.8	244	70 82		
1/18/80 56 psi	ANX-2	1010	Raw Untreated	55	2930	1700	≤10	17.9	248	73.6	873	5843
1/18/80	ANX-2	1010	Filtered	55	2930	1736	≤10	17.9	250			4939

Figure 3

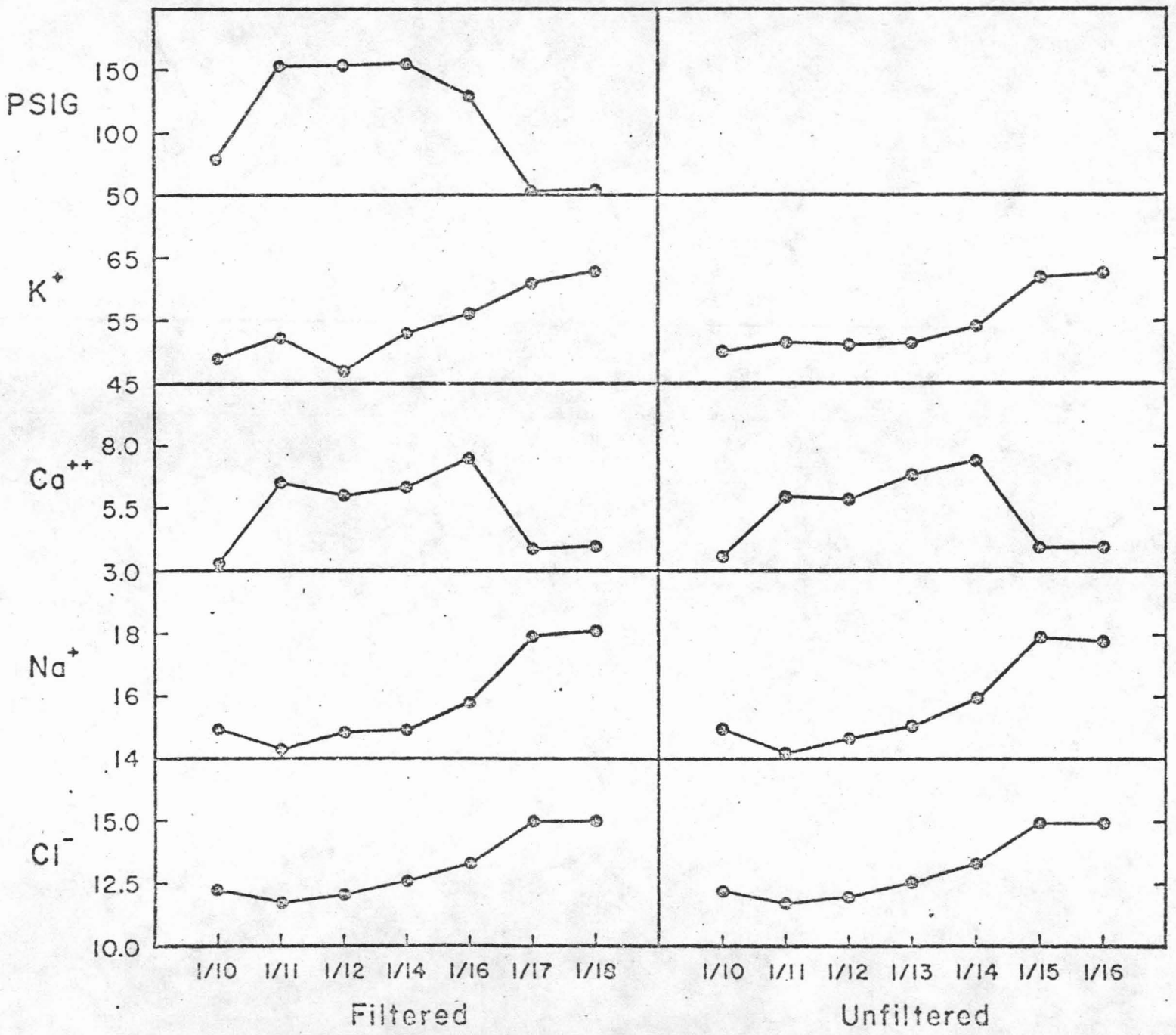
Major Ion Chemistry of Brine



Ion Concentrations Expressed as Percent of Seawater Mixtures. Highest and Lowest Concentrations are as Indicated.

Figure 4

Major Ion Concentrations
Normalized to Percent Seawater



alteration mineral chlorite, which is abundant in cores from the deeper parts of HGP-A. The removal of calcium ion can be effected in two ways: by the formation of calcite and by precipitation of anhydrite. Both of these minerals have been identified in small amounts near the bottom of HGP-A and in grab samples of material scraped from the inside of the well bore. Anhydrite has a retrograde solubility product and it is not known at present whether the increased concentrations of calcium and sulfate brought about by flashing of the reservoir fluid exceeds the higher solubility product of anhydrite in the adiabatically cooled brine. We are presently attempting to acquire the data necessary for the solubility calculations in the original reservoir fluids and in the flashed brine.

Figure 4 presents plots of the chloride, sodium, calcium, and potassium concentrations in filtered and unfiltered brine against separator pressure at the time of collection. It is apparent that all the ions plotted respond to changes in separator pressure as would be expected for different flashing fractions of the well fluid, however, the calcium ion concentration responds in the opposite manner to the other ions plotted. This behavior suggests that the calcium carbonate-dissolved CO_2 equilibrium is controlling the calcium concentration in the liquid phase. At higher separator pressures the dissolved CO_2 concentration in the brine can maintain a $CaCO_2$ concentration of approximately 0.85 millimolar whereas at lower separator pressures the concentrations are maintained at approximately 0.45 millimolar. We are presently in the process of acquiring additional data in an effort to determine whether calcite solubility is controlling the dissolved calcium concentrations at the higher separator pressures. If the calcium concentrations in the brine are the calcite:carbon dioxide equilibrium concentrations then it must be assumed that calcite is being deposited either in the aquifer or in the well bore.

The nearly identical ion concentrations observed in the filtered and unfiltered brines suggest that there is very little particulate material present in the brine phase, however, this cannot be stated as a firm conclusion until analyses of the acidified brines are completed.

Calculation of the reservoir temperature through application of the silica and sodium-potassium-calcium geothermometer was attempted. In every case the calculated temperature was at least 50°C below the observed reservoir temperature confirming the inapplicability of these geothermometers in the Hawaiian environment.

Isotope Chemistry

Table 2 presents tritium analyses performed on selected samples of the well discharge water through the duration of the test as well as a few samples taken prior to the extended well discharge.

Tritium analyses done on discharge water from earlier production tests of HGP-A have yielded values of approximately 0.2 TU or less thus indicating that the reservoir water for HGP-A is older than approximately thirty years (pre-homb). It can be concluded then that the tritium present in the recent discharge water is derived entirely from water pumped into HGP-A prior to the well rework; the activity of the quench water was approximately 7.93 TU (Fire Hydrant Sample). Several hypotheses are suggested by the tritium data:

1. Discharge samples collected from the silencer overflow immediately after the well rework had an activity of 4.0 TU, however, samples collected after a long period of shut-in several weeks later had a substantially higher activity. This strongly suggests that two aquifers were being produced during the 10/17 discharge: a "high tritium" aquifer which received the bulk of the quench water and a "low tritium" aquifer. The increase in tritium following the three-week shut-in can probably be attributed to circulation within the well bore between the two aquifers. Downhole water chemistry samples taken subsequent to the January 18 shut-in strongly suggest that this type of circulation pattern is continuing and that the "high tritium" reservoir is of a lower salinity than the "low tritium" reservoir. If this is the case, it can be concluded that the majority of the HGP-A production is from a low salinity aquifer, at bottom hole, and that a somewhat lower pressure/less permeable saline aquifer is producing at a shallower level.

2. Samples taken during the January discharge have a substantial amount of tritium still present. This would suggest that circulation within the reservoir

Table 2

Isotope Analyses of HGP-A Discharge

Sample Source	Date Collected	Tritium Act. (T.U.)
Well head	11/09/79	6.48 ± 0.91
Fire Hydrant	11/09.79	7.93 ± 0.97
Silencer Overflow	10/17/79	4.00 ± 0.56
Weirbox	12/28/79	2.31 ± 0.40
Weirbox	01/03/80	2.08 ± 0.37
ANX-2	01/12/80	1.32 ± 0.42
ANX-2	01/18/80	0.50 ± 0.38

Sample Source	Date Collected	^{14}C Activity	Age
Well head	05/08/77	21.34% NBS (1950)	12,800 ± 200 years
Well head	05/08/77	18.19% NBS (1950)	13,600 ± 200 years
ANX-1	01/18/80	22.85% NBS (1950)	12,203 ± 142 years

is relatively slow compared with the fluid withdrawal rate during production from the HGP-A reservoir.

3. The correlation between decreasing concentrations of high tritium-low salinity quench water and the increasing chloride concentration in the discharge fluids strongly suggests that the rate at which the chloride ion was increasing was substantially higher than its natural rate would have been had there been no quench water present. It is highly probable that the rate at which the chloride ion concentration was increasing would have slowed considerably had the test been continued longer than fifteen days.

Carbon dioxide

Samples were obtained for ^{14}C analysis of the gases being discharged from HGP-A. The results of these analyses are puzzling at best. Carbon-14 is present at a level equivalent to 20% of modern activity which corresponds to a maximum average carbon age of approximately 12,000 years. This age assumes no contribution from magmatic carbon dioxide; if one assumes magmatic carbon is present then the actual age of the non-magmatic component would be younger by the assumed proportion of magmatic carbon. The apparent ages of the carbon dioxide samples taken during the January 1980 test are virtually identical to an earlier ^{14}C analysis of HGP-A gases done in June of 1977. Although there are several possible sources of carbon in the well, there are only two which could reasonably supply the non-magmatic carbon in the well: organic material pumped into the well during drilling operations or calcite which has been deposited from groundwater circulated through the rift zone. Whether either of these sources could provide the seemingly constant proportion of ^{14}C to the well fluids is questionable. Continued monitoring of the ^{14}C in the fluids during production will be required before a more definite source of ^{14}C in the well can be identified.

Non-Condensable Gas Compositions

During the production-test of HGP-A the composition and concentration of non-condensable gases in the steam phase were monitored using two separate sampling and analysis techniques. The first procedure applied was as follows: steam from ANX-1, downstream of the well head separator, was passed through a second portable separator and into a condenser coil. The steam and dissolved non-condensable gases were then admitted to a cascade type liquid-gas equilibrator; the gas and liquid fractions from the equilibrator were each metered and the gas composition was analyzed using draeger tube samplers. This procedure was found to be very useful in making rapid semi-quantitative analysis of the gases being released, however, the solubility of H_2S and other gases did not permit the use of this method as a quantitative analytical technique.

The second procedure used for analysis of the non-condensable gas content requires both gas chromatographic analysis and titrametric analysis. Samples of the steam discharge at ANX-1 were condensed directly into an evacuated flask containing a caustic solution. The acid gases, CO_2 and H_2S, are absorbed by the caustic and the non-acid gases N_2 and H_2, released into the flask head space. The major components of the head space gases were analyzed first, with a gas chromatograph, and then samples of the caustic and the absorbed gases are analyzed by titration using specific ion electrodes and a pH electrode. This procedure is a standard technique and can give a quantitative analysis of the gases present.

Table 3 presents a selected set of the most reliable analytical results obtained for the non-condensable gas compositions during the January test; several difficulties encountered during start-up prevented us from obtaining reliable data prior to January 10, 1980 for the acid gases and January 14, 1980 for the permanent gases. Comparisons between earlier data on HGP-A non-condensable gases (Table 4)

Table 3

Non-condensable Gas Analyses for January Production Test

(expressed in mg/Kg of steam)

Date sampled	H_2S	CO_2	N_2	H_2	Total	Separator Pressure
01/10/80†	704	825				88
01/11/80†	782	864				154
01/13/80†	766					156
01/14/80†	837	930				156
01/15/80*	825	900	195	10.9	1931	155
01/16/80†	760	1010	169	11.0	1950	155
01/17/80*	875	1000	168	11.0	2054	96
01/18/80*	880	783	117	8.9	1789	56
01/18/80*	860	760	108	6.4	1734	56

†field analysis

*laboratory analysis

H_2S, ppm

@ Sep press = 155 psi →	STEAM	BRINE	TOTAL	TOT NCG	ANN = H_2S
	790	16	306	1960	410

$$\frac{790-10}{306} = 96.3\% \text{ or } 97\%$$

Table 4

Non-condensable Gas Analyses From Prior Well Tests

(expressed in mg/Kg of steam)*

Date Sampled	H_2S	CO_2	N_2	H_2	Total	Sampling Pressure Psig
02/09/77	1363	3773	796	44.0	5976	370
02/09/77	1433	4429	729	48.0	6639	370
02/09/77	748	1974	lost	lost		25
05/08/77	873	2378	375	15.2	3646	~10
05/08/77	556	1478	536	15.9	2586	167
07/19/77	111	455	116	23.4	705	350
07/19/77	434	1689	255	11.7	2390	~10
07/19/77	165	1042	374	3.7	1585	150

*These values were reported in mg/Kg of <u>total discharge</u> in prior discussions of the non-condensable gas chemistry.

and those obtained during the January test strongly suggest that the total non-condensable gas content may have decreased substantially. It should be noted, however, that the earlier samples were taken using considerably less elaborate equipment and the analytical techniques used on those samples were not as accurate as those applied in the recent test. Nonetheless, an analysis of the probable errors involved in the earlier procedures suggests that the previously reported values were probably low relative to the actual non-condensable gas concentrations present, thus the conclusion that the total non-condensable gas concentrations have probably decreased still appears to be valid.

Although there are several potential explanations for the apparent decrease in non-condensable gas content, the one which is most consistent with the data is that gases are being preferentially mined from the reservoir during production. Whether the source of the non-condensable gases being withdrawn are in the form of dissolved carbonate and sulfide or whether they are from the remobilization of carbonate and sulfide minerals connot be determined at present. Although New Zealand geothermal reservoirs have shown a similar trend of decreasing non-condensable gas concentrations, the proposed mechanism does not appear to be applicable in the Hawaiian geologic environment. Whether the trend of decreasing non-condensable gas content will continue in the future cannot be determined with the presently available data. Although there are also apparent changes in the relative ratios of the non-condensable gases, we have found that the differences observed are artifacts of the earlier analytical techniques and that the more recent analyses are more representative of the non-condensable gas compositions present.

It is apparent from the data presented in Table 3 that there is a substantial variation in the gas compositions and concentrations through the duration of the test. This can, in large part, be attributed to changes in steam quality at the

different separator pressures; as the separator pressure is increased the steam fraction is decreased substantially whereas there is relatively little change in the total amount of gas discharged. The net result is that at higher separator pressures (and lower steam fractions) the relative amount of non-condensable gas in the steam phase increases. Although it is theoretically possible to use the gas compositions at different separator pressures to determine the fluid enthalpy as well as several other down-hole geochemical and production parameters, we will not be able to perform this type of analysis until further analytical data have been obtained.

In addition to the major components of the non-condensable gas fraction, minor amounts of several other gases were also found to be present. The trace gases detected in the steam discharge included helium, argon, carbon monoxide, and possibly methane. None were present in concentrations greater than 2-3 ppm of the steam phase. Although ammonia and mercury were analyzed for, neither were present at the detection limits for the technique applied. Further analyses are being persued for these species.

The non-condensable gases dissolved in the brine discharge were also monitored during the production test. The data acquired are presented in Table 5 under the column heading ANX-2. Hydrogen sulfide in the filtered brine (non-particualte) varied from a high of 16.3-16.4 mg/Kg, at pressures of 128 to 155 psi, to a low of 12.4 mg/Kg, at a separator pressure of 55 psi. Carbon dioxide dissolved in the brine phase varied in a similar manner with a high of 202 mg/Kg and a low of 165 mg/Kg. These results are consistent with the other chemistry observed and are important primarily in terms of the H_2S abatement procedures for the brine discharge. Gas samples were also taken in conjunction with the hydrogen sulfide removal procedures instituted for the production test.

Although gas sampling was attempted at ANX-3, ANX-4, ANX-5, and in the steam plume above the sparger box, it is believed that none of the techniques applied were satisfactory for quantitative monitoring of the H_2S emissions. The specific difficulties encountered were as follows: for samples taken at ANX-3, -4, and -5 the very low steam pressures rendered the available steam-water separator virtually useless whereas sampling of the mixed gas/liquid discharge at these points would have yielded erroneously high H_2S results regardless of the analytical techniques applied. For samples of the steam plume, draeger analyses were undoubtedly low as a result of variable air mixing in steam above the rock muffler whereas samples taken of condensate from the plume gave unrepresentatively high sulfide values due to partial condensation of the steam phase and its consequent loss from the gas phase. These difficulties are best demonstrated by analyses made using both techniques on January 5, 1980; draeger analyses of the steam plume yields 7.2 ppm H_2S while a steam condensate sample of the plume yields 101 ppm H_2S. Work is presently underway in an effort to develop a somewhat more accurate means of determining the H_2S composition in the steam plume.

Draeger analyses of sulfur dioxide in the steam plume were even less successful. The detection reagent in the SO_2 sensitive tubes was highly soluble and thus steam condensate effectively washed most of the reagent away. None of the sulfur dioxide analyses done by draeger tube should be considered reliable. Wet chemical analysis of steam condensate at ANX-5 was, however, able to place an upper limit on the steam discharge at less than 10 mg/Kg.

Conclusions

- In general terms the geochemical subtask associated with the production test of HGP-A can be considered a success; a considerable amount of information has been obtained concerning the gas and water chemistry of the HGP-A effluents and further

results are expected from continuing analyses of the water and gas samples obtained. A more complete discussion of the implications of the geochemical data obtained will be attempted when the results of the remaining chemical analyses are available.

Table 5

Geochemical Field Data for January Production Test of HGP-A

Date	Weirbox	ANX-1	ANX-2	Sparger	Other Sampling Points	Well head Pressure Psig	Separator Pressure Psig
01/03/80	0925 Cl^- 1546 1015 Cl^- 1405 1115 Cl^- 1356 1215 Cl^- 1366 1315 Cl^- 1375 1515 Cl^- 1366 1715 Cl^- 1396 2115 Cl^- 1457			2315 H_2S=3[5]		0925 155 1015 125 1115 112 1215 70 1315 90 1515 300 1715 315 2115 184	2115 136
01/04/80	1345 Cl^-=1733	1400 H_2S=154[5]	1330 H_2S=22.7[1] 1340 H_2S=22.3[1]	0845 H_2S=<30[6] 2130 H_2S=7[6]		1315 148	1315 132
01/05/80	1130 Cl^-=2008 2145 Cl^-=2125	1230 noncondensable gas=0.1% H_2S=150[5] CO_2=1400[5] H_2S=458[3]		1030 H_2S=12[6] 1208 H_2S=5800[7] liquor H_2S=7.2[8] H_2S=101[9]		1130 140 2145 120	1130 124 2145 97

Date	Weirbox	ANX-1	ANX-2	Sparger	Other Sampling Points	Well head Pressure Psig	Separator Pressure Psig
01/06/80	1245 Cl^-=2250 1700 Cl^-=2300			1345 H_2S=1[6] in plume 2045 pH=6[8] 2400 pH=5-6[8]		1245 119 1700 217	1245 104
01/07/80	0900 Cl^-=2372 2125 Cl^-=2415			0340 pH=5-6[8] plume 0645 pH=6[8] plume 0900 pH=6[8] plume 2200 pH=6[8] plume		0900 118 2125 191	0900 103 2125 148
01/08/80	0930 Cl^-=2650			0055 pH=6[8] plume 0415 pH=6[8] 0745 pH=6[8]			
01/09/80	0745 Cl^-=2784 2145 Cl^-=2680	H_2S= 9% of total N.C. gas H_2S= 170[5]	2025 H_2S=14.8	1935 pH=7[8] pH=5[8] 2050 H_2S=210[6] 2100 H_2S=70[9] plume cond.	ANX-1-A 1200 Cl^-=1730 ANX-1-A 2100 H_2S=186	0745 60 2145 103	2145 87.2

Date	Weirbox	ANX-1	ANX-2	Sparger	Other Sampling Points	Well head Pressure Psig	Separator Pressure Psig
01/10/80		1130 H_2S=456[3] H_2S=447[3] CO_2=505[4]					
	1143 Cl^-=2733	1200 H_2S=704[4]				1143 103	1143 88
		1300 H_2S=710[4] CO_2=825[4]	1300 H_2S=16 CO_2=194[1]	1340 H_2S=4780[7]	ANX-1-A 1734 SiO_2=1240		
			1740 SiO_2=1520				
	2145 Cl =2633		2145 Cl^-=2390 Cl^-=2376			2145 165	2145 152
01/11/80	0950 Cl =2728	1000 Cl^-<30[3]				0950 166	0950 154
		1300 H_2S=503[3] CO_2=429[3]	1300 Cl^-=2450[1] Cl^-=2280[1] H_2S=16.3[2] brine filt. CO_2=202[2] brine filt				
		1400 H_2S=782[4] CO_2=864[4]		1400 S_2=12590[7]eff 2235 pH=5[8] steam cond.			
01/12/80			1620 H_2S=11.8				
	2000 Cl^-=2850			1725 $S^=$=4057[7]eff		2000 168	2000 156

Date	Weirbox	ANX-1	ANX-2	Sparger	Other Sampling Points	Well head Pressure Psig	Separator Pressure Psig
01/13/80		1400 H_2S=766[4]		0555 pH=5.5[8] 1830 H_2S=5[8] H_2S=7[8]			
01/14/80			1100 H_2S=15[2] CO_2=200[2]	0755 H_2S=20[6]	ANX-4 1105 pH=6.5-7.0 ANX-4 1300 pH=6.0		
		1400 H_2S=837[4] CO_2=930[4]		1405 H_2S=25[6] SO_2=125[6]	ANX-3 1430 $S^=$=270		
		1520 H_2S=427[3] CO_2=534[3]		1710 SO_2=100[6] H_2S=8[6]	ANX-1-A 1800 Cl^-=1900 ANX-1-A 1830 Cl^-=2746		
	1930 Cl=2910			1925 H_2S=15[6] SO_2=240[6] 1950 SO_2=100[6]	State Point 2 2245 χ^{10}=50.4% χ^{10}=53.4%	1930 165	1930 156
				2300 SO_2=100[6] H_2S=3[6] 2400 SO_2=100[6] H_2S=5[6]			

Date	Weirbox	ANX-1	ANX-2	Sparger	Other Sampling Points	Well head Pressure Psig	Separator Pressure Psig
01/15/80					ANX-4 0230 ph=4 ANX-4 0510 pH=11 ANX-4 0755 pH=11		
				0805 H_2S=6[6] SO_2=100[6]			
					ANX-3 0930 $S^{=}$=11200 CO_3=1423		
	0945 Cl^{-}=3016 $S^{=}$=2.6				ANX-4 0945 $S^{=}$=7890 CO_3=2110 ANX-5 0945 $S^{=}$=28.1 CO_3<50	0945 165	0945 155
				1820 SO_2=N.D. H_2S=N.D. 1900 CO_3=4420[7] eff			
01/16/80				0600 H_2S=20[6]			
	1845 Cl^{-}=3114	1845 H_2S=760[4] CO_2=1010				1845 137	1845 128
				2245 H_2S=10[6] CO_2=0[6]			
						2400 X^{10}=56.5%	

Date	Weirbox	ANX-1	ANX-2	Sparger	Other Sampling Points	Well head Pressure Psig	Separator Pressure Psig
01/17/80		1000 CO_2=1000[4]	1300 H_2S=16.4[2]	0230 H_2S=12[6] 0700 H_2S=4[6] 1730 H_2S=6-8[6] SO_2=0[6]	ANX-5 2130 SO_2<10	χ^{10}=63.6%	
01/18/80	1315 Cl^-=3265	1230 H_2S=476[3] CO_2=400[3]	1215 Cl^-=2910[2] 1230 Cl^-=2930[1] 1245 H_2S=12.4[2] CO_2=165[2]	1240 $S^=$=338[7] $CO_3^=$=4260[7]	ANX-3 1240 $S^=$=17,900 $CO_3^=$=2850 ANX-4 1240 $S^=$=30.5 $CO_3^=$=2620	1315 70	1315 55

[1] Unfiltered brine

[2] Filtered brine

[3] Steam condensate from condenser coil

[4] Steam and gas discharge condensed into NaOH solution

[5] Gas analysis by draeger tube

[6] Draeger tube analysis of steam plume

[7] Wet chemical analysis of sparger box liquor

[8] Plume condensate

[9] Plume condensate into NaOH solution

[10] χ = steam quality

TABLE X

The Compass Headings from the Geothermal Plant for Schroeder, Gilman, Hess, and Wood Monitoring Stations and the Proportion of Hours with Concentrations Greater Than 5ppb Which Fit in a 60 Degree Directional Cone Extending from the Plant, 1983.

Residence	Azimuth	Direction From Plant	Wind Direction From Plant	Proportion
Schroeder	196	SSW	346-046 NNW-NE	8/14=57.1%
Gilman	268	WSW	058-118 NE-ESE	4/19=21.1%
Hess	230	SW	020-080 NNE-ENE	0/1 = 0%
Wood	026	NNE	176-236 SSE-SW	7/115=6.1%